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Understanding Business Requirements for Increasing the Uptake of Recycled Plastic: A Value Chain Perspective

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Abstract: Circularity and recycling are gaining increased attention, yet the amount of recycled plastic applied in new products remains low. To accelerate its uptake by businesses, it will be useful to empirically investigate the barriers, enablers, needs and, ultimately, requirements to increase uptake of recycled plastic feedstock for the production of new plastic products. During the six focus group sessions we conducted, a value chain approach was used to map the factors that actors face regarding the implementation of recycled materials. The identified factors were structured based on three levels: determining whether a certain factor acted as a barrier or enabler, identifying the steps in the value chain that the factor directly affected and the category it could be subdivided into. The results were then further processed by translating the (rather abstract) needs of businesses into (specific) requirements from industry. This study presented eight business requirements that require actions from other actors in the value chain: design for recycling, optimised waste processing, standardisation, material knowledge, showing possibilities, information and education, cooperation, and regulation and government intervention. The main scientific contributions were the value chain perspective and the applied relevance of the findings. Future studies may delve deeper into the individual factors identified.

Keywords: plastic recycling; barriers; enablers; business uptake; business requirements; value chain

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1. Introduction

Plastic is a widely applied material due to its many benefits and inherent properties: it is cheap, very light, durable, fast and efficient to manufacture, heat resistant and non-reactive, making the material suitable for a wide range of applications. As a result, plastic has become indispensable over recent years, fuelling demand and worldwide adoption [1]. Although the functional lifespan of plastic products is potentially hundreds of years, the material often remains a lot longer than a plastic product could actually stay in use and be fit for purpose. Since the demand for plastic is expected to increase in the coming years whilst resources become further depleted, it is important to utilise plastic waste in a more resourceful way [2].

Currently, European waste management approaches are not resource efficient. Current systems and measures in the EU lead to 95% of the value of plastic packaging materials being lost after a short first use [3]. Much pre-segregated and mixed waste plastic is being incinerated. This represents a lost opportunity, as research has shown that the majority of plastic can be recovered and reused in new products [4]. Industry, society and policy makers are becoming aware of these possibilities, indicating a shift in mindset towards a circular economy (CE), whereby products and materials are kept in use by designing out waste and pollution [5].

Accordingly, the European Commission has introduced a European Strategy for Plastic in a Circular Economy [6], setting out their vision for a circular plastics economy. This

document outlines the challenges, strategies and opportunities employed to achieve more circular production and consumption of plastic products [1]. A key approach towards realising a circular plastics economy is recycling. The European Commission envisions major changes by 2030, such as making all plastic waste 'easily' recyclable and the creation of markets for recycled plastics [6]. European targets were set to recycle 50% of all plastic packaging by 2025, with some countries adopting even more ambitious targets, such as 70% by 2025 in the Netherlands [7] and the UK [8], and 63% by 2022 in Germany [9]. The EU also set goals in relation to the percentage of recycled content in plastic products, requiring a minimum of 25% recyclate in PET bottles [6]. Again, individual countries set their own goals in excess of this, such as 35% recycled content in single-use plastic products and packaging in the Netherlands [7] and an average of 30% recycled content across all plastic packaging in the UK [8].

Despite circularity and recycling gaining increased attention in Europe, only 32.5% of the total plastic waste stream was collected for recycling in 2018 [3]. Plastic packaging waste has a somewhat higher recycling rate of 41% in 2019 [10]. This leaves room for the further exploitation of opportunities to recycle plastic waste [11]. To reach the higher recycling rates and increase recycled content in new plastic products and packaging, it is necessary to identify and compare the various factors that influence the uptake of recyclate by businesses.

The main goal of this research was to understand the requirements to increase the uptake of recycled materials and their incorporation into new products. In order to understand what businesses need from other actors in the value chain, it is important to first map the challenges businesses encounter; the enabling factors that allow them to use recycled materials; and the instruments, resources and circumstances they need to further increase their uptake of recycled materials. Hence, this research empirically investigated the main barriers and enablers that organisations encounter and their needs when using recycled plastic feedstock to produce new plastic products. These factors are mapped across the value chain to identify how they influence a certain stage. Key industry requirements for increasing the uptake of recyclate by manufacturers were drawn from these results and further explored and elaborated upon.

This study was funded by the Interegg North-West Europe programme. Hence, the scope of this research was limited to this area, with businesses and organisations from the Netherlands, UK and Germany participating in the research. Moreover, the focus was placed on post-consumer waste. This was because plastic derived from post-consumer sources represents additional challenges for recycling compared to industrial plastic waste, which already benefits from regular streams of mono-materials, existing recycling channels and a simpler value chain. Moreover, this study focused on the mechanical recycling of materials. Alternative processes, such as chemical recycling (i.e., converting plastic waste back into its monomers to be repolymerised back into virgin-quality plastic) are acknowledged; however, they are considered beyond the scope of this research.

The general outline of this paper is as follows: Section 2 covers a theoretical background, reviewing current literature to provide a general understanding of the factors that influence circularity and recycling. Thereafter, the method for empirical research, i.e., the use of several focus group sessions, is explained in Section 3. Results are presented in Section 4, which forms the basis for the discussion and conclusion presented in Sections 5 and 6, respectively.

2. Theoretical Background

Although there is increasing attention towards circularity and recycling in Europe and a growing number of organisations are willing to implement such practices, CE implementation has seen little progress [11–13], with limited plastic recycling [11] realised in practice. Hence, it is important to identify and compare the various factors that influence the implementation of circular practices in relation to plastic waste [14].

2.1. Barriers and Enablers for Plastic Recycling

Since recycling is regarded as being indispensable for closing the loop [1], it is often discussed in line with circularity [15]. Circularity can be regarded as an overarching 'umbrella' concept, with many barriers and enablers applying to various circular strategies (e.g., consumer demand). Such factors were widely explored in the current circularity literature; for example, see [12,16,17]. Other studies focused on barriers and enablers that are more specific to plastics (for example, see [11,18]) and/or recycling (for example, see [1,2,19]). Such studies included issues that specifically apply to recycling (e.g., lower material quality), with some only applying to a certain industry or product segment (e.g., regulations for food contact).

According to Hart et al. [16], most CE research has a broad focus, but each sector and product differs and more tailored approaches are necessary. However, we aimed to take a broader approach to all plastic sectors, as the waste of one sector may become input for another. In other words, if the material quality is too low to be applied in one product (category), it may still present opportunities for cascading uses in other products or within other sectors. Moreover, waste that is unsuitable to be used in one production process may present opportunities for the use of other technologies.

The current literature shows several ways of categorising barriers and enablers [16]. For instance, Kirchherr et al. [12] proposed a categorisation of cultural, regulatory, market and technical factors, while Hart et al. [16] distinguished between cultural, regulatory, financial and sectoral factors. Tura et al. [17] took a more extensive approach and classified barriers and enablers into seven different categories: environmental, economic, social, institutional, technological and informational, supply chain and organisational factors. For this research, we assessed the different categories and, based on this comparison, we made a distinction between regulatory and policy, economic, technical, systemic, organisational and cultural factors.

Although some studies specifically focused on factors that influence the recycling of plastics, most research is focused on the issues, and the inclusion of enablers remains limited. Moreover, the analysis presented to date has been relatively superficial, lacking in-depth analysis and discussion. Previous research suggested that the relevance of an issue may differ per stakeholder [12] and may thus be experienced differently by actors from different parts of the value chain [16]. Additional empirical research may help to illustrate how different actors are (indirectly) affected by various barriers and enablers [17]. Therefore, it will be valuable to analyse the barriers and enablers for all actors along the value chain and investigate how this will subsequently affect manufacturers and their decision to incorporate recycled plastic feedstock in new products. Furthermore, a clear overview of the barriers, enablers and needs, as well as their relation to different stakeholders along the chain, helps to illuminate the importance of relationships (e.g., some enablers may only support uptake when certain barriers have first been eliminated) and identify solutions that address the concerns of multiple actors.

2.2. Mapping the Plastic Value Chain

A CE requires a systems perspective and the rethinking of supply chains, business models [20] and, subsequently, the whole life cycle of products and materials [1]. Such fundamental changes cannot be achieved by a single organisation or single person [1]; instead, they involve activities at different parts of the value chain, which must be considered simultaneously [13]. Figure 1 presents a visual representation of the plastic value chain, which includes three distinct stages: (1) material sourcing and production by manufacturers; (2) sale and usage by customers and consumers; and (3) collection, sorting and reprocessing by waste management companies. To ensure all these processes are synchronised, collaboration from all actors in the plastic value chain is needed.

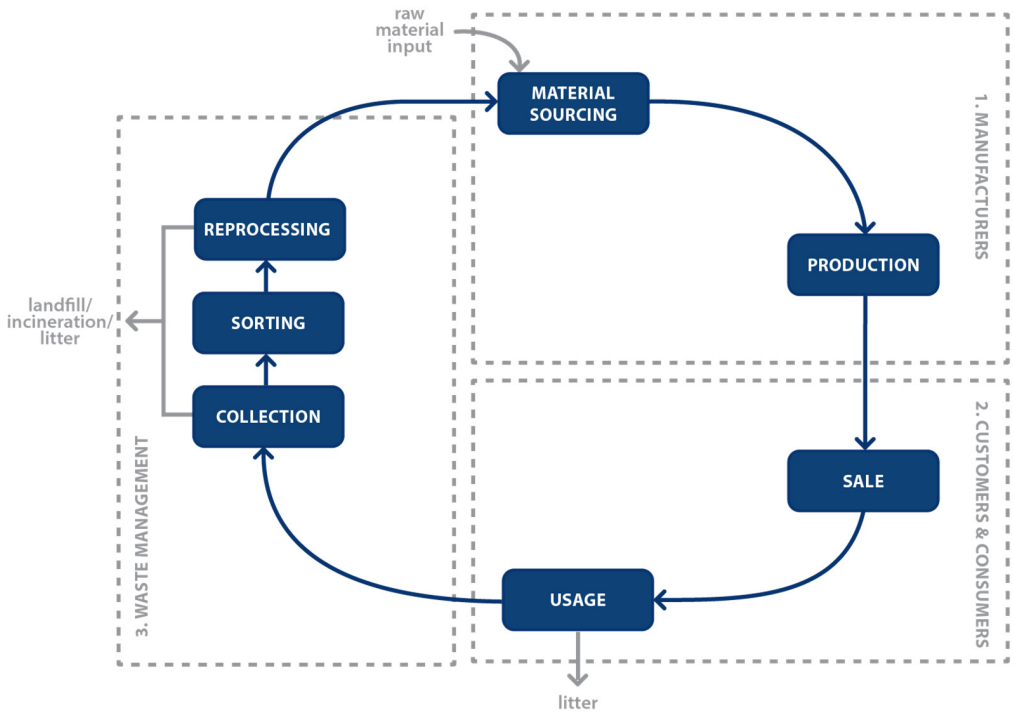

Figure 1. Plastic value chain.

However, the current situation suggests that the plastic industry remains underdeveloped and siloed when it comes to recycling [2,13,14]. The findings of Milios et al. [2] highlight that there is a lack of both supply and demand for recycled plastics, mainly due to the fragmented market. This lack of integration throughout the value chain is regarded to be a major barrier to enabling circularity [13]. In line with this, several other studies pointed out that increased value chain cooperation is needed; for example, see [1,2,14]. To facilitate successful collaboration between various actors, it is important to first understand what challenges different organisations face at each step in the value chain.

Despite increasing literature on the barriers and enablers for recycling, little attention has been paid to the assessment of the complete value chain, from the generation of waste to using recyclate as feedstock for new plastic products [2]. In line with this, several other authors argued that there is a need for a more systemic and holistic approach; for example, see [1,17]. A value chain analysis is a widely used approach in research; for example, see [1,2,21,22]. Integrating such a systemic perspective will allow solutions to be sought along the value chain [1]. Accordingly, Milios et al. [2] conducted research using a sub-market approach, enabling mapping interactions between key actors. The authors proposed a value chain approach, identifying barriers that occur in each step of the chain, as well as overarching factors or those that may affect activities two or three steps up or down the chain [2].

Therefore, this study also took into account which step(s) in the value chain the identified barrier or enabler had a direct influence on, whether this involved a single step, multiple steps or encompassing the complete value chain. This will ultimately help to understand business needs at different points in the value chain, identifying requirements and opportunities for increasing the uptake of recycled materials by manufacturers.

The main research gaps identified through the literature review were: (1) limited addressing of enablers to stimulate the uptake of recyclate and a lack of in-depth analysis and discussion of needs, (2) little attention to the challenges faced by different actors in the value chain, and (3) a lack of an integrated approach assessing how certain influences on actors also indirectly affect manufacturers and their decision to incorporate recycled plastic feedstock in new products.

3. Methods

This research started with a literature review to achieve a general understanding of the barriers to and enablers of recycling. After that, additional empirical research was completed to reveal practical insights into the current situation in industry and to identify the various barriers, enablers and needs that organisations experience with the uptake of recycled plastic. To gather the necessary information, two focus group sessions were completed per country (The Netherlands, UK and Germany) with various actors in the plastic industry. These results were then processed to identify requirements.

3.1. Focus Groups

The main goal of this empirical research was to explore the factors that influence the uptake of recycled plastic materials by businesses. Focus groups were chosen as a method to bring about interaction between actors and aid understanding of the various perspectives. During the focus group sessions, participants actively engaged in mapping the barriers and enablers affecting the uptake of recycled plastic feedstock. Based on this, the participants identified business needs. By sharing their experiences, know-how and knowledge about the use of recyclate, participants had the opportunity to learn from each other. Hence, the goal of the focus group sessions was threefold: first of all, to identify barriers and enablers for the uptake of recycled materials by businesses; second, to understand the needs of businesses; and third, to facilitate knowledge exchange between actors in order to facilitate further elaboration.

The focus group discussions were facilitated through MS Teams, with a length of two hours each. After an introduction, participants were divided into separate breakout rooms in order to have smaller groups (3 to 8 participants). In the breakout sessions, the following aspects were discussed: a brief introduction of participants; an introduction of the plastic value chain, including the various steps for manufacturing and recycling plastic products; an inventory of barriers and enablers, as well as positioning them at the right step in the value chain; identifying the needs of businesses; and subsequently, highlighting the most important factors. In each session, an online canvas was used to map these factors with sticky notes at different parts of the plastic value chain. The workshop ended with a plenary wrap-up in which the most important factors of each breakout group were presented.

Several organisations from different positions in the value chain participated in the focus group sessions, representing businesses, consultancies, academics, governmental organisations and waste management companies. Participants were selected in order to cover different stages in the value chain. This meant that each session consisted of actors from different backgrounds, providing a good understanding of the industry as a whole. In total, 81 people from 74 different organisations participated in the six focus group sessions.

3.2. Categorisation of Barriers and Enablers

A growing number of scholars have been researching the factors that (potentially) influence the implementation of circular practices, leading to multiple ways of structuring these factors. In this research, factors that influence the uptake of recycled feedstock are structured based on three levels. First, it was determined whether a certain factor acts as a barrier or enabler. The distinction between a barrier and enabler was made depending on the current situation and results of the focus group sessions. If a factor is not applied in industry (yet), is hindering (optimal) recycled applications or is not correctly applied at this moment, it was classified as a barrier. If a factor was perceived to stimulate recycled applications or is already applied to some extent, but may further stimulate the uptake of recycled materials, it was classified as an enabler. Hence, the absence of an enabler does not necessarily imply that recycled plastic cannot be used. As an example, optimised waste separation and sorting was classified as an enabler because, within the current system, recycled plastic can still be used in products. Yet, the situation may be improved via optimised waste separation and sorting, which will lead to higher-quality outputs and, in turn, an increased uptake of recycled materials. In contrast, contamination of waste

streams was classified as a barrier since contamination will prevent a certain batch from being applied as recycled material.

Second, which part of the plastic value chain the factor is (directly) influencing was established: material sourcing, production, sale, usage, collection, sorting and reprocessing (also see Figure 1). Determining the steps in the value chain where problems may occur makes identifying the issues more tangible and will allow for the easier adoption of recycled materials. Individual factors could directly influence a single step, multiple steps or the complete value chain.

Third, which category the factor could be subdivided into was defined. As previously explained, distinctions were made between regulatory and policy, economic, technical, systemic, organisational and cultural factors.

3.3. Processing Results to Identify Needs and Requirements

After structuring and categorising the focus group results, all factors were presented into one overview. Within one table, barriers and enablers were structured based on the three previously mentioned levels. Based on the findings, a short description was made per category, summarising how factors in that category influence (a certain part of) the value chain, and subsequently, uptake by businesses.

In order for businesses to be able to successfully apply recycled materials, some actions are required from other actors along the value chain. During the focus group sessions, certain needs of businesses were identified, which were later translated into specific requirements of other actors. In a business context, needs can be described as 'goals and objectives a business must achieve', whereas requirements are 'the things we need to do in order to achieve a need' [23]. Hence, to stimulate the uptake of recyclate by businesses, it is important to convert (rather abstract) business needs into (specific) requirements. These requirements then need to be fulfilled by other actors in the chain.

Therefore, when processing the results, we distinguished between business needs (e.g., bigger demand for recycled materials) and requirements (e.g., optimised waste processing). In the end, requirements were described according to their position in the value chain, to identify the relevant actors and provide more specific insights that will help to develop goal-oriented actions.

4. Results

The results of this research led to an overview of the barriers and enablers for the uptake of recycled plastic in new products, and subsequently, the needs and requirements.

4.1. Barriers and Enablers for the Uptake of Recycled Plastic

Several barriers and enablers for the uptake of recycled materials emerged during the focus group sessions. The outputs were combined and are presented in Table 1. For each category, a summary of the factors is presented below.

4.1.1. Regulatory and Policy Factors

When it comes to regulatory factors, instruments have been employed to encourage both circularity and recycling; however, there is a lack of clear (and stimulating) policies and regulations. The application and enforcement of such policies and regulations are seen as important instigators for the realisation of recycling objectives and increased uptake of recyclate within industry. However, it was observed that regulations, particularly many of those currently in place, can also have the opposite effect, hindering businesses from using recycled materials rather than supporting them. For example, the use of recyclate for food purposes is currently limited to rPET (recycled polyethylene-terephthalate) because of strict requirements and standards for materials in contact with food. When it comes to stimulating policies, businesses are asking for financial incentives to support the use of recycled materials, minimal usage requirements to level the playing field, and tools to aid quick and easy product comparisons.

Table 1. Overview of barriers and enablers per category and their position in the value chain.

Category	Barrier/Enabler			Position in Value Chain						
		Barrier	Enabler	Material sourcing	Production	Sale	Usage	Collection	Sorting	Reprocessing
Regulatory and policy factors	Misalignment of regulations	x								
	Financial stimulation		x							
	Minimum recycled content requirement		x							
	Public awareness		x							
	Lack of enforcement of waste legislation	x								
Economic factors	High costs of recycling	x								
	Price competitiveness of recyclate	x	x							
	Fluctuating costs	x								
	New markets and applications		x							
	Increased prices for consumers	x								
	Cost for research and development	x								
	Reluctance to invest in more expensive recycling methods	x								
	Lack of economies of scale for new investments	x								
	Investment costs for capital and infrastructure	x								
	Supplier transaction costs	x								
	Long-term contracts for more security of investments		x							
	Growing demand from existing markets	x								
Technical factors	Contamination of waste streams	x								
	Optimised waste separation and sorting		x							
	New material innovation	x								
	New technologies for recycling		x							
	Design for recyclability		x							
	Material quality issues	x								
	Inconsistent material quality	x								
	Unknown material quality	x								
	Availability of material data/information		x							
	Combination of polymer type and used production process	x								
	Use of materials with better properties than required	x								
	Application possibilities	x								
	Lack of colour options	x								
	Lack of design freedom	x								
	Quality assurance	x								
	Slower production process	x								
	Additional testing	x								
Systemic factors	Systems perspective		x							
	Closed-loop recycling		x							
	Matchmaking platform		x							
	Lack of infrastructure	x								
	Standardisation of recycling processes		x							
	Increased recycling capacity		x							
	Lack of a reliable stream of material	x								
	Standardisation for (quality of) recyclate		x							
	Standardisation of product designs		x							
	Technology, data and traceability		x							

Table 1. *Cont.*

Category	Barrier/Enabler	Position in Value Chain								
		Barrier	Enabler	Material sourcing	Production	Sale	Usage	Collection	Sorting	Reprocessing
Organisational factors	Internal organisation and decision making	x								
	Lack of innovation culture	x								
	Business tendency towards short-termism	x								
	Circularity reporting		x							
	Existing manufacturing infrastructure	x								
Cultural factors	Consumer demand and acceptance	x	x							
	Unwillingness to pay	x								
	Difficulty in gaining market share	x								
	Lack of customer requests	x								
	Limited visual appearance of recycled products	x								
	Lack of experience from product designers	x								
	Recycled material as a basic requirement		x							
	Setting unnecessary high standards for products of recycled materials	x								
	Resistance to change	x								
	Perception of (recycled) plastic	x								
	Lack of knowledge, information and education	x								
	Awareness creation		x							
	Information about possibilities		x							

The x indicate whether a factor is classified as a barrier or enabler and the grey shade indicates the positioning in the value chain.

4.1.2. Economic Factors

From an economic perspective, a major barrier is the cost of recycling materials. These expenses result in knock-on effects for other actors in the chain, such as increased costs for manufacturers and, eventually, higher-priced products for consumers. For manufacturers, a key factor seems to be the fluctuating price differentials between virgin and recycled materials and the resulting uncertainties, which can discourage investments and make business planning difficult. Achieving a higher-quality recyclate typically requires additional sorting and processing steps compared to lower-quality recyclate, resulting in higher costs. The higher costs for achieving high-quality materials may result in businesses typically using recyclate of lower quality than possible, with the possibility of putting them off long-term, even though higher-quality materials could be possible. For some materials, there is an insufficient supply of waste plastic by volume for recycling to be economically viable.

For consumers, product prices are not only higher due to the use of more expensive resources, but also because of additional processing steps and testing. The lack of consumer demand for products made of recycled materials is seen as one of the key economic barriers for businesses to using recycled materials, as demand is needed to make any long-term investments. Evidence from circular applications shows that the upscaling of recycling processes could solve cost issues and may lead to a situation where recycled materials are favoured. Optimising the recycling process and reaching economies of scale will help with decreasing the prices of recycled materials and making them more competitive with virgin variants.

4.1.3. Technical Factors

Technical factors mainly relate to the recyclability of materials and the quality of recyclate. This starts with contamination within waste streams, which may be caused by residuals or incorrect waste separation by consumers. During the recycling process,

there are still many problems that cause certain products or packaging to hinder or disturb sorting and recycling. Products may be too small to be sorted (e.g., bottle caps), as they are filtered out by sieves during the first steps of the recycling process. Some materials have no separate stream due to their lack of volume. Furthermore, there are problems with the mixing of colours and not being able to differentiate between food and non-food materials. A lack of design for circularity implemented at the early stages of product design can also exacerbate the challenges faced during sorting and reprocessing. Hence, aspects such as designing products fit for recycling, improving the overall recycling process and the use of new and improved (more efficient or cost-effective) recycling technologies are seen as major enablers for improving the quality and technical performance of materials. Nonetheless, uncertainty about material quality is often seen as a greater barrier than the quality standard itself. Hence, creating a certain 'material passport' and improving the sorting of materials are keys to enabling this.

The composition and quality of materials will further determine the production and application possibilities of recyclate and, in turn, the (physical appearance of) products made from recycled materials. In some cases, this may lead to the overspecification of products (e.g., the use of food-grade recycled materials for non-food products, leading to shortages of recyclate suitable for food applications). However, for certain products (e.g., when safety is important), no deductions should be made, as quality, safety and durability are decisive. Opportunities are seen to strengthen critical parts by using extra materials, providing extra support for that part or, as the last option, using virgin materials only for the critical parts of products. Moreover, the 'greyish' look of recyclate significantly limits the diversity of colour possibilities, where specific colours used for marketing purposes are difficult to make or will deviate from current colours. White or clear recyclate is therefore more desired by businesses and comes with a higher price. In line with lower material quality, certain material characteristics (e.g., melt flow) may differ for recycled materials, which could lead to limitations in product designs. The varying properties of recycled materials and the uncertainties about quality will also lead to the need for additional testing and slower production processes.

4.1.4. Systemic Factors

For businesses to take up recycled plastic feedstock, the whole value chain needs to be involved. The expansion and improvement in waste collection and sorting infrastructure and services are important drivers for the uptake of recycled plastics by industry. These drivers are also considered essential for securing a (reliable) supply of plastic waste that is consistent in terms of composition and availability.

The lack of standards in industry leads to many different ways to collect waste, sort it and reprocess it into recyclate. It is regarded as beneficial for industry to aim for more standardisation of processes and information so that actors can be more in line with one another. Standardisation in industry is required for the recycling process, quality of recyclate and product designs. Moreover, there is a potential for new technologies to achieve material traceability.

4.1.5. Organisational Factors

For an organisation to opt for recyclate over virgin materials, different actors and departments have to agree. This could lead to obstacles and time delays. The lack of an 'innovation culture' from businesses contributes to a conservative and cautious approach, leading to 'linear economy lock-in'. Top-tier leadership and a clear vision from directors and decision makers may help to stimulate innovation, including from the bottom up, which could support the use of recycled materials. Moreover, businesses seem to be setting goals with deadlines in the distant future, whereas a greater impact could be realised if more short-term goals were established.

Businesses have the opportunity to create a point of differentiation between their products and those of their competitors by highlighting their environmental and sustain-

ability credentials. Therefore, conducting environmental product analysis, such as life cycle analyses (LCAs), and mapping environmental cost indicators and the total cost of ownership (TCO) are seen as drivers for the uptake of recycled materials. Whilst this alone may not be sufficient to attract buyers (i.e., the products still need to function and appear as good as existing products), it can help to generate marketing materials and brand identity.

4.1.6. Cultural Factors

From a cultural perspective, a major barrier for businesses is the lack of consumer demand. This may be caused by the misperception of recycled plastic, increased prices and/or lack of consumer awareness. Lack of demand, willingness and acceptance not only comes from consumers but also from business-to-business (B2B) customers, with subsequently little incentive for manufacturers to explore possibilities for the use of recyclate. Throughout the value chain, there exists cynicism about the effectiveness of recycling, a resistance to changing everyday behaviours, and a perception or misconception around the (lower) quality and performance of recycled materials. For businesses, there is a reluctance to change, producing a 'linear economy lock-in' that leads to a lack of commitment to solving the problems associated with single-use plastic and an aversion to risk taking. Virgin materials are often still seen as the optimal standard for production and purchasing. Customers and/or consumers often have a certain idea of the visual design of a product in mind. If these expectations are not met, there is a risk of losing customers to competitors with virgin plastic products that meet the required appearance. The high demands of businesses and consumers may also lead to the overspecification of products. More flexibility in terms of material properties, appearance (e.g., the use of black or dark black) and quality is required from manufacturers, customers and consumers.

Due to the negative reputation of plastic, consumers are often not aware of the benefits of the material, nor of the positive impact of recycling. There may also be nuances in this, such as 'green consumers' who see plastic as 'bad' and avoid it altogether and 'regular consumers' who just want 'new, clean' plastic because it is 'better'. In contrast to the general image of plastic, the perception of recycled materials may be associated with being dirty, unhygienic (e.g., in Asia), unsafe (e.g., PVC) or of lower quality. Such issues can lead to resistance within organisations. This requires education of and awareness-raising within industry and society in order to increase knowledge. Lack of knowledge is a common issue across the complete value chain, ranging from recyclers and manufacturers to customers and consumers. Hence, there is a need to increase knowledge, share information and showcase possibilities by presenting examples, such as the best practices and pilot projects.

4.2. Needs and Requirements for Further Uptake of Recycled Plastic

The outcomes of the focus group sessions resulted into several needs and requirements. These findings ranged from rather abstract business needs (e.g., bigger demand for recycled materials) to more tangible requirements for what other actors have to do (e.g., optimised waste processing) in order to meet the needs of businesses. These findings are visualised in Figure 2 based on the value chain steps they have a direct influence on. Factors can have a direct effect on (1) (other) manufacturers, (2) customers and consumers, (3) waste management companies, or (4) have an overarching effect across all actors in the value chain.

As visualised in Figure 2, the needs of businesses include: prices that are equal to or cheaper than virgin materials, a reliable stream of recyclate, improved material quality, higher quality end products, greater acceptance within the sector, flexibility from customers and an increased demand from customers and consumers.

To achieve the needs of businesses, more specific requirements first have to be met, involving the complete value chain. As an example, regulation and government intervention are key, as these are essential limitations to address for recycled materials to achieve equal or cheaper prices to virgin materials, to create a reliable stream of recycled materials and to create a bigger demand for recycled materials.

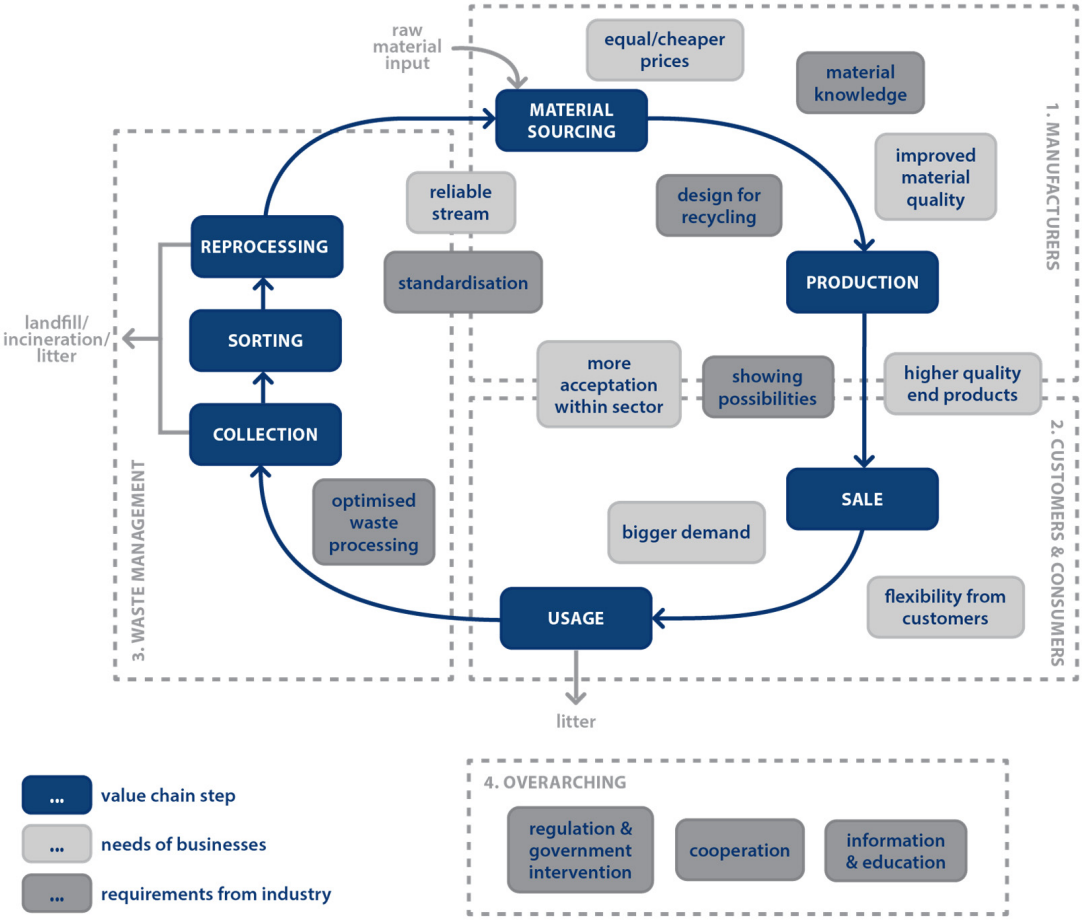

Figure 2. Overview of business needs and requirements from industry laid out on the value chain.

As shown in Figure 2, the requirements were structured along the value chain, with each requirement influencing a certain part of the chain, multiple parts or across all. Each requirement is further explained below to identify how it influences the depicted part in the value chain and to better understand what can be done to increase uptake by manufacturers.

4.2.1. Design for Recycling

To improve the recyclability of materials, it is essential to make sure products are designed for disassembly and ease of recycling. There are currently many problems that cause certain products or packaging to hinder or disturb sorting and recycling processes, such as the use of certain materials (e.g., PVC); a combination of materials (e.g., multilayers and composites); certain colours (e.g., carbon black); or the use of certain additives, inks or adhesives. Taking such aspects into account within the design of products will help to limit problems with sorting and recycling, and will subsequently lead to higher material quality. Since many businesses are still unfamiliar with the recycling process and lack the knowledge to design products fit for recycling, it will be essential for industry to provide information about 'bad' product designs and show solutions that can be used to design for recyclability. Such information should be easy to find, as well as free and accessible to the general public.

4.2.2. Optimised Waste Processing

An important requirement for increasing material quality is a coordinated and optimised collection and sorting system. For some regions, this includes expanded waste collection, with plastic or packaging waste being separately collected. Additional sorting steps may help to further limit contamination, reducing the proportion of unusable

plastics. Opportunities present themselves when using new and advanced technologies for better sorting. Barcode scanning uses invisible digital watermarks for more efficient sorting, for example, allowing food products to be sorted separately. Other techniques may involve colour sorting of products for further dividing material streams by colour. Investments by companies in all parts of the value chain are required for testing and using such technologies, but also for increasing the recycling capacity. With the optimisation of recycling processes, recycled materials will be of higher quality, increasing the willingness of businesses to use recycled materials. Moreover, it will lead to a more consistent material quality over time, a reliable stream and lower costs for recycled materials.

4.2.3. Standardisation

To decrease uncertainties associated with recycled plastics, standardisation in industry is required. This involves standardising the recycling process so that products can be designed to fit the same recycling process. Currently, sorting and reprocessing systems differ per country, but may also differ within one country. Standardising the recycling system may also help with creating a standardised range of disposal icons for packaging labels. Furthermore, standardisation is required for (the quality of) recyclate. This also comes along with the need to determine (quality) requirements for recycled materials. Furthermore, standardisation is required for product designs. More neutral designs would simplify and improve the recyclability of products and packaging. This may include fewer material options, less colour variety or the use of lighter colours, but also includes standardisation for the used inks, adhesives, labels and additives. Last, the standardisation of products may help organisations to invest in new sorting and recycling processes and achieve a return on investment.

4.2.4. Material Knowledge

To allow for easier processing of (varied) lower material qualities, businesses require an in-depth knowledge of materials. Defining the quality and properties of the used recyclate will allow manufacturers to adjust their approaches and production processes accordingly and will help them to better determine application possibilities. Material knowledge and properties could, for example, be included in a 'material passport'. Such a passport may be more relevant for bigger products that are separately collected, while technologies such as 'barcode scanning' may help with determining properties during the sorting of packaging and smaller plastic products. Furthermore, there is a potential for new technologies to record data relating to materials as they progress through the product lifecycle and subsequent recycling processes. As a driving force for plastic recycling, technologies including blockchain, big data and connected products (e.g., smart packaging) may help to achieve material traceability, supporting extended producer responsibility enforcement. The insights generated may also help to keep track of the supply, volume and location of plastic wastes, helping businesses to plan and allocate resources accordingly.

4.2.5. Showing Possibilities

It is important for industry to show possibilities for the use of recyclate in new products so that it will be easier for other businesses to follow their example. Best practices and pilot projects should be showcased in industry and various media. The dissemination of such information may serve as inspiration for other businesses to do the same and is an important driver for the widespread replication and upscaling of solutions. Insights into the activities of other companies will not only show that they are doing it but also how they do it. This could help increase business confidence and give practical tips for businesses looking to follow suit.

4.2.6. Information and Education

More information and education are required by and from all actors in the value chain. Manufacturers require technical knowledge relating to application possibilities,

material quality and properties, safety requirements, machine settings, etc. Businesses also require more practical information on how to design products for recycling, with a need for the education and upskilling of designers in relation to recyclability. Consumers require more information on product disposal and collection systems, and for them to see the consequences of their incorrect sorting. Moreover, it is important to raise public awareness of the importance of using recycled plastic materials in place of virgin plastic and to address recycling behaviours to build trust and drive behavioural change in relation to buying and disposal practices. Across the complete value chain, actors require more information on the benefits of circularity and recycling and the consequences of plastics that are only used once. This comes along with information and education in relation to recycled and recyclable materials, recycling processes, disposal options and manufacturing options for the use of recyclate.

Hence, educating industry and society seems necessary. Training, instructions, tools and educational resources are important for improving the recyclability of materials (by design), the adoption of required recycling behaviours by the public and the uptake of recyclate by businesses. Consultancies, knowledge institutes, governments and media could help to distribute such information to the wider public. Furthermore, circularity reporting of businesses could help industry and society to understand the impact of products and the materials being used.

4.2.7. Cooperation

In order for any individual business to take up recycled plastic feedstocks, all stages of the value chain need to be established and functioning effectively. Any disconnect or breakdown in communication between key stakeholders could disrupt the entire system, requiring a joined-up systems perspective and a collaborative approach. This involves recognising the importance of integrating a systems perspective and open communication between partners and stakeholders. On both the customer and supplier sides, businesses need to cooperate to define requirements and standards. Moreover, it is important to find the right partners to work with.

At the same time, there is a need for value chains to be organised more efficiently. Opportunities need to be found for implementing local recycling practices for closed-loop recycling. Buy-back options could be offered for products that have reached their end-of-life stage to ensure recycling possibilities. It could also be useful to establish a platform where businesses and recyclers can find each other and sell recyclate.

4.2.8. Regulation and Government Intervention

Governmental stimulation is seen as a key driver for businesses to use recycled feedstock, and there is a strong need to increase regulation and government interventions. At a financial level, this includes initiating subsidies for the use of recycled materials, introducing taxes for using virgin materials, or launching federal or state funding programmes to establish efficient disposal and recycling routes. Non-financial interventions may include setting requirements for a minimum percentage of recycled materials to be used in products, offering options for environmental product analyses to businesses, further implementation of extended producer responsibility via contractual agreements, or providing information and including the public in decisions and debates on waste policy.

Moreover, businesses require clear regulations rather than the current abstract goals for the (near) future (e.g., reaching recycling objectives or a circular economy in 2050). They also require more clarity on regulations, and for regulations to be aligned with the situation in industry, with less restricting requirements regarding regulations that currently prevent the use of recyclate (e.g., for food or skin contact).

5. Discussion

This research started by highlighting the barriers and enablers that currently influence the uptake of recycled materials by businesses. Comparing the results based on a value

chain perspective, we observed that some factors were more important for certain steps in the value chain because they directly influenced the organisation but may also (indirectly) influence the activities of other actors further up or down the chain [2]. As an example, the contamination of waste streams does not directly influence manufacturers; however, lower quality recyclate as a result of contamination directly affects the uptake by businesses. This may illustrate a possible chain reaction, which was also suggested by Kirchherr et al. [12] to occur between different categories (e.g., low virgin material prices (economic) resulting in lacking consumer interest (cultural)). In contrast, other factors apply to the complete value chain (e.g., design for recycling or standardisation for (the quality of) recyclate). Although this research suggested that there are interrelations between factors, additional research is necessary to map such relations in more detail.

Previous research suggested that the relevance of a factor may differ per stakeholder [12] and may thus be experienced differently by organisations from different parts of the value chain [16]. We also argue that this includes the context in which the organisation operates (e.g., the material that is being processed, product category, physical appearance of product or used production process). As an example, some manufacturers find virgin materials to be cheaper than recycled materials, whereas for others, this is the other way around. Such price differences could be caused by the quality of the materials that are being used. When lower-quality plastics (e.g., mixed streams) are used, the prices of recycled materials seem to be cheaper than virgin materials, whereas higher-grade (mono) materials often seem to be more expensive compared with virgin alternatives. Another example relates to the product that is being manufactured. If a company's main business is to manufacture products for public spaces, food-grade material is not required and thus seems to be less of an issue. Such differences in the relevance of a factor may come along with uncertainties in industry.

After identifying the various barriers and enablers that influence the uptake of recycled materials, the results were translated into business needs, and subsequently, into requirements from other actors. Though the latter is more tangible, it is important to mention that such requirements may also bring about new barriers, in line with the research of Hart et al. [16]. As an example, designing products that are fit for recycling is required to stimulate the uptake of recycled materials by businesses, but there will be further barriers to adopting this in practice. For example, for some packages, there may not be a suitable alternative that is 100% recyclable or there may be a lack of knowledge and skills regarding designing products that are fit for recycling.

The requirements listed in this study focus on actions required from other actors along the chain. However, as can be seen from the list of barriers in Table 1, there may also be organisational barriers (e.g., lack of innovation culture). These internal barriers of an organisation were not taken into account here because of the value chain perspective of this study. Researching organisational (change) factors will be a study in itself and has to be further researched.

Further research on barriers and enablers may further explore the importance of relationships, as some barriers may be more limiting than others and/or some enablers may only support uptake when certain barriers have first been eliminated. For example, there is no point in addressing material sorting issues if the pricing of recyclate is the limiting factor for manufacturers, meaning they will not decide to use recyclate even if the supply is of high quality. In this sense, it is also important to consider feedback loops. For example, the lack of supply may restrict uptake because manufacturers need reliability and consistency; however, a surplus of material could reduce the price paid for recyclate, which would put recycling companies out of business.

Although the main topic of this study was the uptake of recycled plastic feedstock in new products, it is important to note that realising a circular plastic economy goes further than only applying recycled materials and designing products that are fit for recycling. Other circular strategies, such as the repair and reuse of products, offering products as a service and organising product take-backs, will be essential in achieving a

circular economy. Barriers, enablers, needs and requirements for such strategies will have to be further researched.

The theoretical and practical implications of this research require additional research related to: mapping the relations between different factors, uncertainties because of different perspectives due to an organisation's value chain position and operating context, new barriers formed by putting the requirements into practice, researching the organisational (change) factors in relation to the implementation of the requirements, and the importance of barriers and requirements and whether eliminating a certain barrier or multiple barriers will result into the uptake of recyclate. This leads to the need for scholars to study the found insights in more detail and empirically research how this can be applied in practice.

6. Conclusions

The objective of this study was to understand business requirements for increasing the uptake of recycled plastic. Based on a value chain perspective, barriers and enablers for using recycled plastic feedstock for the production of new plastic products were identified and categorised into regulatory and policy, economic, technical, systemic, organisational and cultural factors.

The barriers and enablers were then translated into the needs of businesses: equal or cheaper prices to virgin materials, a reliable stream of recyclate, improved material quality, higher-quality end products, more acceptance within the sector, flexibility from customers and a bigger demand from consumers. However, to stimulate the uptake of recyclate by businesses, it is important to convert (rather abstract) business needs into (specific) requirements. This study presented eight business requirements that require the actions of other actors in the chain.

First of all, designing products that are fit for recycling is important to limit problems with sorting and recycling, and will subsequently lead to higher material quality. Second, optimised waste processing and the use of newer technologies are required for more consistent material quality over time, a reliable stream and lower costs for recycled materials. Third, standardisation of the recycling process, material quality and product designs are important for increasing quality, simplifying the chain and decreasing uncertainties for businesses. Fourth, material knowledge will allow manufacturers to adjust their approaches and production processes accordingly and material traceability is important to keep track of the supply, volume and location of plastic waste. Fifth, showing possibilities in terms of best practices and pilot projects is required to increase business confidence and provide practical tips. Sixth, information and education are required in terms of technical knowledge, practical insights, information about disposal options, demonstrating the benefits of recycling and raising public awareness. Seventh, the cooperation of actors, open communication and organising the value chain more efficiently are required for any individual businesses to take up recycled plastic feedstock. Last, the regulation and government intervention in terms of subsidies, taxes, funding programmes, minimum usage requirements, options for product comparisons and providing information are required, with more clarity and alignment of regulations.

This was an initial, exploratory study with a relatively small sample size, which allowed for the collection of detailed, qualitative data and in-depth analysis. This highlighted several barriers, enablers, needs and, ultimately, requirements for the industry if North-West Europe is to realise a circular economy for plastic waste. It is expected that the results of this study will lay the foundation for future studies that delve deeper into the individual factors identified.

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